# The Banality, but importance of parasitism

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We often treat parasites as if they are these rare things that occasionally crop up and cause problems. And understandably so! Being sick is terrible. Epidemics bring illness and even death to many and pain and suffering to most. If only we could just get rid of these few nuisance species! Wouldn't the world be a better places?

What I want to convince you of is that neither of these perspectives are right. Parasites are far from rare, but the plague-causing pathogens are. Indeed, parasites are so common and usually cause so little harm that most of the time we do not even notice them. In other words, we should not think about parasitism as some special case where *something* went wrong, but as the normal state of the world; common, even banal!

## Parasites are common!

Parasitism is the most successful strategy or means of making a living. It is more common than photosynthesis, herbivory, or carnivory, perhaps more common than all of them combined! That is because every single species on Earth has at least one species parasitizing it. From what I can tell we have never looked carefully at a species and *not* found it being parasitized at least occasionally. Even parasites have parasites![1] And many of these parasites specialize on just one or a few host species[2]. The numbers work out such that nearly half of all species on earth are thought to be parasites.

Think about yourself. You have *huge* numbers of things infecting you, even in this highly sanitized, carefully controlled world! You are host to a myriad of viruses, masses of bacteria, the occasional fungus (athlete's foot, yeast infections) or helminth (tapeworms, pinworm, roundworm), and perhaps lice or ticks on occasion, or the rare apicomplexan (*Babesia*, *Toxoplasma*). And that's if you've been lucky and fairly healthy! The fact that we are infected by so *few* parasites speaks to centuries of improved sanitation, food safety, and, to a smaller extent, medicine.

Another way to think about it is that virtually every taxon has some members that we would think of as parasites. Sure, the microparasites like viruses[3], bacteria, and fungi seem obvious, but we can find representatives in less obvious places, too! For instance, huge numbers of wasps are parasites, as are flies and fleas and bees. Plants like mistletoe and Indian pipe are parasites of trees and mycorrhizal fungi, respectively. Cowbirds and cuckoos are brood parasites, laying their camouflaged eggs in the nest of some other species, who then take care of them like their own, even after these young parasites kick out of the nest their adopted siblings. One of my favorite examples is *Sacculina*, a genus of *barnacles* (!) that parasitize and

[1] These are sometimes called hyper-parasites. There can even be hyper-hyper-parasites!

[2] The question of why so many parasites are specialists while others are generalists is a very deep one, and fodder for a century of evolutionary biologists.

[3] A special case. We know of no non-parasitic viruses.

castrate crabs. Their larvae find a chink in the armor of a crab (e.g., at a joint) and then inject themselves into the crab, grow a large sac of developing eggs on the crab's thorax, where it's own eggs would be, and manipulates the host crab into taking care of this parasites eggs as if they were her own! What's more, if the barnacle gets onto a male crab it will feminize it and convince it that it is a pregnant female, too! There are too many examples to do justice to the diversity of parasites!

## Parasites are not some minor player to be ignored

Parasites can have a major role in the world around us. Setting aside the fact that this one novel coronavirus that popped up recently has completely remade our world, there are many examples throughout history where parasites have changed history, ecosystems, or both (e.g., the Black Plague, Rinderpest, Smallpox). But parasites are also important to the larger world more broadly and often. Let us consider two marine examples that illustrate the commonness and potential importance of parasites.

First, consider viruses in the oceans. They make up a surprisingly large amount of biomass in the ocean. One estimate[4] suggested that viruses comprise 94% of all nucleic acid-containing particles, that is 19 in 20 things floating in the water with a genome[5]. Even though any given virus particle weighs a negligible amount, combined they still count for some 5% of prokaryotic biomass. The amount of carbon[6] in these viruses is estimated to be equivalent to that in 75,000,000 blue whales[7]!

What do those bazillions of viruses do? Well, they replicate and in the process most lyse or break open their host cells. Viruses of phytoplankton thus kill and break open their phytoplankton hosts—estimates are on the order of 10–40% of prokaryotic cells per day!—releasing all of their hosts' nutrients into the waters to be taken up by other phytoplankton. This is important when considering the alternative; plankton that die intact drop out of the water column, taking their nutrients with them. No nutrients, no growth. No growth, no converting atmospheric $CO_2$ into biomass. Thus, viruses play an important role in the worlds oceans, facilitating phytoplankton growth and even increasing rates of carbon absorption into deep oceans on a scale relevant to geochemical cycles!

Second, consider the parasites in the birds (and crabs and other animals) found in marine estuaries. One study of three estuaries found that the biomass of just tropically-transmitted[8] and castrating parasites were each roughly equivalent to the biomass of all of the wading birds[9]! Imagine that! In and around all of those wading birds that people come to see is an equal mass of worms and so on, hidden from sight, and for most people's thoughts.

These macroparasites are also important in the energy flow through ecosystems, not simply by releasing nutrients into the water, but through their trophic interactions. These parasites eat things—both literally and metaphorically—and are then eaten, moving energy (ATP, sugars, long-chain carbon molecules more

[4] Suttle, C. 2007. Marine viruses — major players in the global ecosystem. Nat Rev Microbiol 5, 801–812

[5] Multicellular organisms are, by comparison, too rare to bother counting, though their biomass is.

[6] Carbon both represents an important part of an ecosystem and plays an important role in energy flow, hence why an ecologist might report such a focused comparison.

[7] Suttle, C. 2005. Viruses in the sea. Nature 437, 356–361

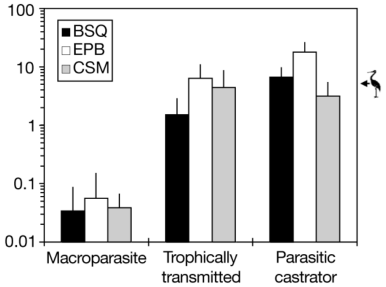


Figure 1: The amount of biomass in different sorts of parasites in three estuaries. The bird icon marks the mean winter bird mass density across the three estuaries (4.1 kg $ha^{-1}$).

[8] That is, transmitted by the infected host being eaten.

[9] Kuris et al. 2008. Ecosystem energetic implications of parasite and free-living biomass in three estuaries. Nature 454:515-518.

broadly) and nutrients along with them. Parasites, especially those with complex life histories, add connections in food webs, providing different routes through which energy and nutrients flow[10], all of which can stabilize food webs.

Sure, most parasite species do not play a major role in ecosystems, let alone have major impacts on the population dynamics of their hosts. But parasites *collectively* are so common, so enormously abundant, and (usually) so tightly integrated into the ecology of their hosts that they matter tremendously! A world without parasites would be a very different place[11]!

[10] Dunne et al. 2013. Parasites affect food web structure primarily through increased diversity and complexity. PLoS Biol 11:e1001579.

[11] Wood & Johnson. 2015. A world without parasites: exploring the hidden ecology of infection. Front Ecol Environ 13:425-434.

## But most parasites have fairly minor impacts on their hosts

Let us return to the wealth of parasites making their living on and in us humans. There are…lots of them. More than I can count anyway. But, importantly, most of them do very little harm to us, at least most of the time. Most of the time, for instance, a cold won't kill you are affect your reproductive output. You have probably survived the occasional bout of food poisoning more or less unscathed. Indeed, measuring the fitness effects of many parasites is very, very tricky because the effects are so subtle.

The British colonial governments, bless their misguided hearts, conducted a great deal of research trying to sort out the impacts of (macro)parasite infections on their laborers and other subjects and did find costs…to production! People with higher worm burdens, for instance, harvested tea more slowly or had to take more breaks in garment factories. But the impacts often only became apparent when considering people with quite heavy burdens.

Indeed, much of the time the worst outcomes occur only in those in the worst of shape already or those with the greatest parasite burden. Tapeworms, for instance, cause little damage to many if not most hosts[12], but they are very problematic in undernourished hosts. *Very* light infections with hookworms (e.g., *Necator americanus*) can cause little if any notable pathology (and some think infections with them and similar helminths prevent autoimmune disorders), but at higher doses they cause severe anemia or worse[13].

What is the point? I want you to realize, in a bone-deep way, that most parasites, most of the time, are far from from the lethal monsters we often imagine[14].

[12] They were once sold for weight loss!

[13] Another clear case of a dose-response!

[14] Parasites need love, too!

I HOPE I HAVE convinced you that while we can certainly find some impressively harmful (and odd!) parasites, these species comprise a very small portion of parasite diversity. Parasites are all around and in us most all the time. They usually cause little obvious harm to us or the animals we care about, at least most of the time. This might be attributed in some degree to our amazing immune systems, capable of wrangling innumerable intruders without us even noticing, and to a degree to the fact that parasites usually have little interest in causing us harm. Indeed, their more important adversaries are often their co-infecting symbiotic neighbors or the harsh environment away from the host. In the end, parasitism is simply a very common way of making a living in the world. It can be hugely important for

hosts and populations and even ecosystems, but more often, it is quite banal.